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September 20, 1989
Our Ref. UT890955

Mr. C. Alan Tapp
Moab Salt, Inc.
P.O. Box 1208
Moab, Utah 84532

Subject: Review of State of Utah Comments dated September 7, 1989 and Additional Subsidence Analyses

Dear Alan,

We have reviewed the State of Utah comments on our Subsidence report dated August 2, 1989. We have also completed additional analyses that address the State's concerns.

The State expressed much concern about the subsidence issue in general, and appeared to be most concerned about the potential effects on the Colorado River. They also are concerned that the solution mining activities may be removing virgin materials from outside the current mining limits which could increase the potential for mine subsidence.

To address these issues, we have performed additional analyses and completed some additional investigations. In order to examine the potential subsidence effects on the Colorado River, we have examined the mined zones closest to the river and calculated the predicted subsidence profile for a "worst case" condition. Figure 1 shows the locations of the profiles that were examined. Figures 2 and 3 presents the cross sections representing the profiles. Of the three cross sections shown, cross section C-C' is the most critical (i.e., would have the greatest effect on the river). From the C-C' in Figure 3 cross section shown, we have calculated an idealized subsidence profile using the procedure outlined in the Subsidence Engineers Handbook (1975). Although this method was developed for longwall coal mining, data on salt-mine subsidence indicates that the method is generally applicable to salt mining for the reasons outlined in our previous report. It is important to understand, however, that the predicted subsidence profile obtained from this method should be considered as an order of magnitude of expected subsidence rather than an absolute value.

For this analysis, we evaluated the potential subsidence along cross section C-C', shown in Figures 1 and 3, using the following assumptions:

Depth to mining	3000 feet
Mined Height	8 feet
Extraction Ratio	100 %
Average width of mining panel	800 feet
Average length of mining panel	2100 feet

The average width of mining was conservatively selected since the section nearest the river is only about 300 feet wide. At the northwest end of the cross section the mined width increases considerably. Subsidence from this area, however, will not substantially effect the area of interest (i.e., the Colorado River). Overall, we consider the analysis performed to provide a "worst case" evaluation of potential subsidence across the Colorado River.

The results of the subsidence analyses are shown in Figure 3. This figure shows the profile of the predicted total vertical displacement above the mining horizon in the direction of the river. The lateral boundaries of predicted subsidence extend approximately 2200 feet from the edge of mined zone, reaching a point approximately 1500 feet east of the Colorado River. Review of Figure 3 indicates that the maximum predicted subsidence at the Colorado River ranges between 0.3 to 0.5 inches. Again, the subsidence values calculated should be considered as order of magnitude estimates that suggest the total subsidence at the river should be less than one-inch. Since this subsidence will occur over an extended period of time and much of the subsidence has probably already occurred, it is hard to envision any substantial effect on the Colorado River. Calculation of horizontal strain and tilt was considered unnecessary given the nature of this problem.

The States second concern seemed to center on the effects of solution mining on the extraction of pillars and possible expansion into virgin salt. Although, perhaps not completely clear in our previous report, we predicted the maximum subsidence above the zones depicted in our report assuming a final 75% extraction ratio and 10 feet of virgin salt removed from the perimeter of the mining areas. The 75% extraction ratio was provided to us by Moab Salt and based on their production records from the solution mining. The maximum predicted subsidence under these conditions was about seven inches. Even if a "worst case" 100 percent extraction was assumed, the maximum predicted subsidence would not increase by more than one-third or to a maximum of about nine inches. Since these numbers should again be considered as order of magnitude estimates, this analysis suggests that maximum subsidence over the panels will be in inches and not in feet and that total maximum subsidence in the area should be less than a foot. Again, much of this subsidence has probably already taken place over the past 20 years and future subsidence may be difficult to measure.

We consider the assumption of 10-feet of virgin salt removed from the mine perimeter to be a reasonable estimate of materials removed since solution mining was initiated. The solution mining records clearly indicate that the pillars are being removed. Since the pillars have two to four times more exposed area per linear foot than the ribs, they should be removed much quicker than the virgin salt exposed along the perimeter. When roof collapses occur, the salt in the collapsed material will be dissolved. Some re-routing of the flow paths adjacent to virgin salt as a result of collapse or closure will likely occur, however, it is our opinion that the dissolution zones will not be sufficient to increase surface subsidence significantly and has already been accounted for in our analysis. Of interest on this subject are the unsuccessful attempts of Moab Salt to develop solution wells that are within 10 to 20 feet of mine workings. These wells were drilled but could never be opened to the mine workings to allow active solutioning to begin. This indicates that, at least in the areas of drilling, the virgin salt had not been dissolved greater than 10 to 20 feet into the ribs which is consistent with our assumption.

The State is also recommending the use of 2-foot contour aerial photography to detect subsidence. This recommendation is not, in our opinion, reasonable for the conditions at the site. The maximum predicted subsidence is less than 1-foot over the mined areas. Since the accuracy of a 2-foot contour map is only $\pm$ 1-foot, it is hard to envision that subsidence could be detected by this method. Our staff has, in the past, attempted to use this method to analyze subsidence above coal mines in Colorado, salt mines in New Mexico, and limestone mines in Missouri. Our experience indicates that subsidence on the order of 2 to 4 feet is required for this method to be successful. As a result, we cannot, given the predicted subsidence magnitude, concur with the State on the recommendation to perform this work.

Finally, the State is requiring a subsidence monitoring network. They indicate that a previous network exists over the area. We have no record of such a network, although we are aware of some unreliable elevations taken on well heads that were subject to large vertical variations with well head pressure. Given the magnitude of the predicted subsidence and that much of the subsidence has probably already occurred (the State apparently concurs with this), a very precise level survey would be required to measure subsidence. It is our opinion that such a network is unnecessary unless some indication of detrimental effects from surface subsidence begins to be observed at the surface.

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We hope this data provides you with the information you need. We would be happy to discuss this further with either you or the State if additional questions arise.

Sincerely,

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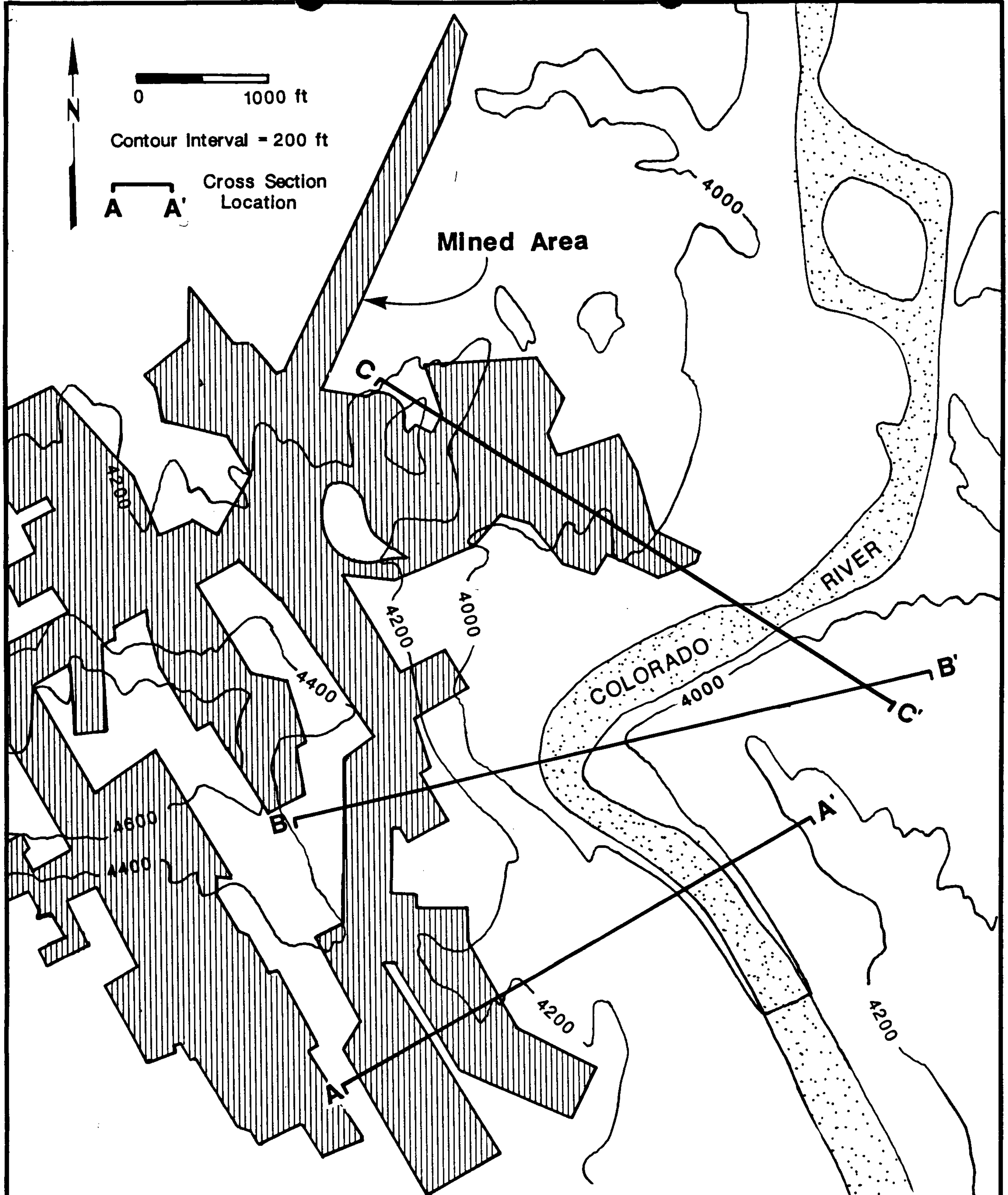
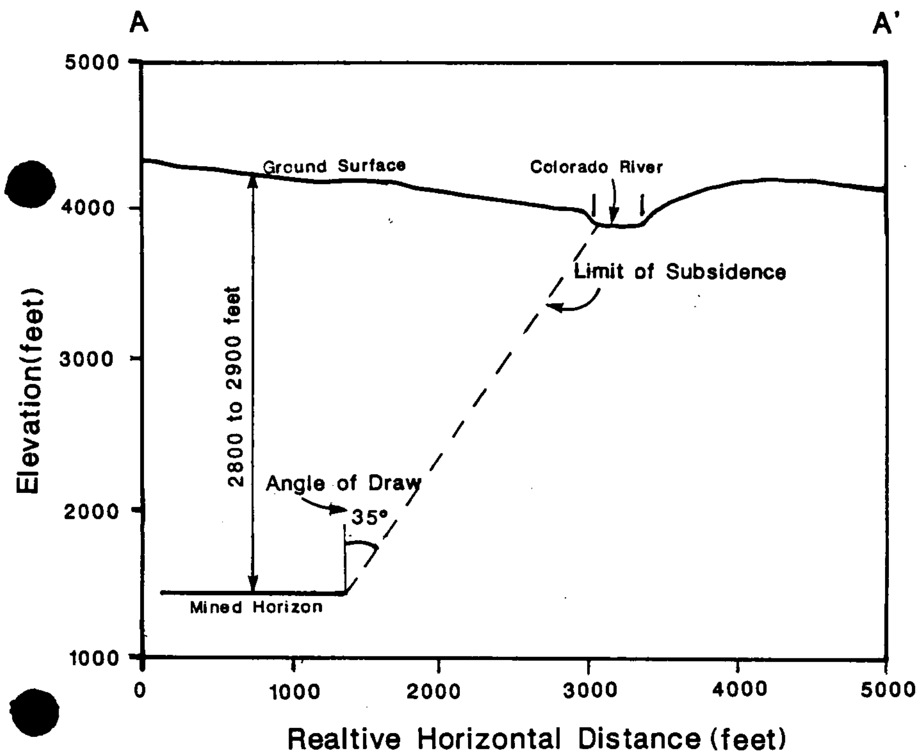
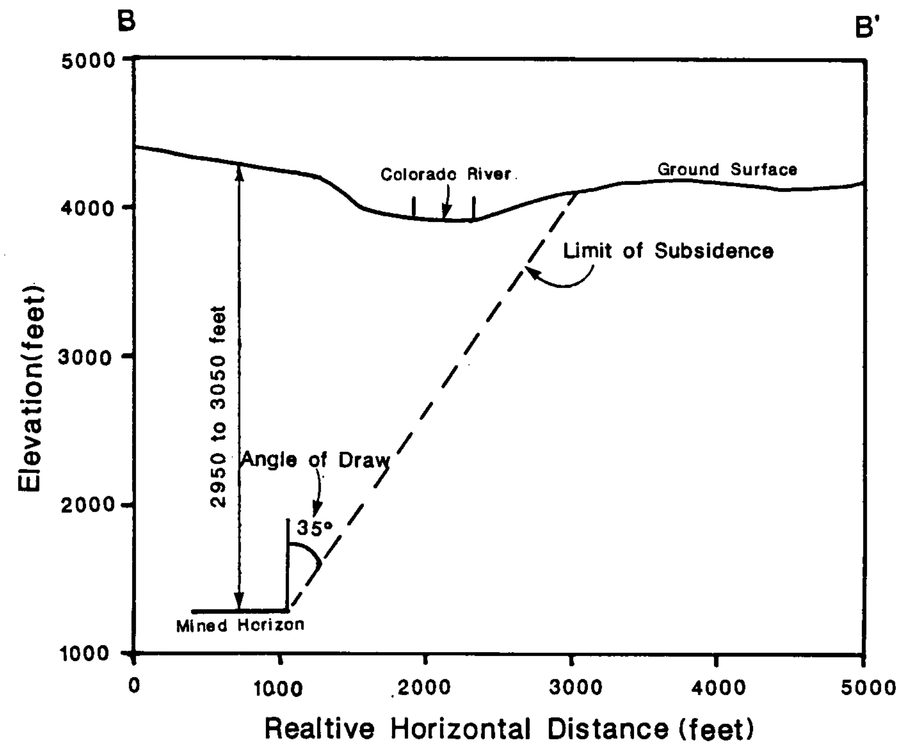


Figure 1

Locations of the Cane Creek Mine and the Colorado River





See Figure 1 for Location of Cross Sections

Figure 2

Typical Cross Sections A–A' and B–B'

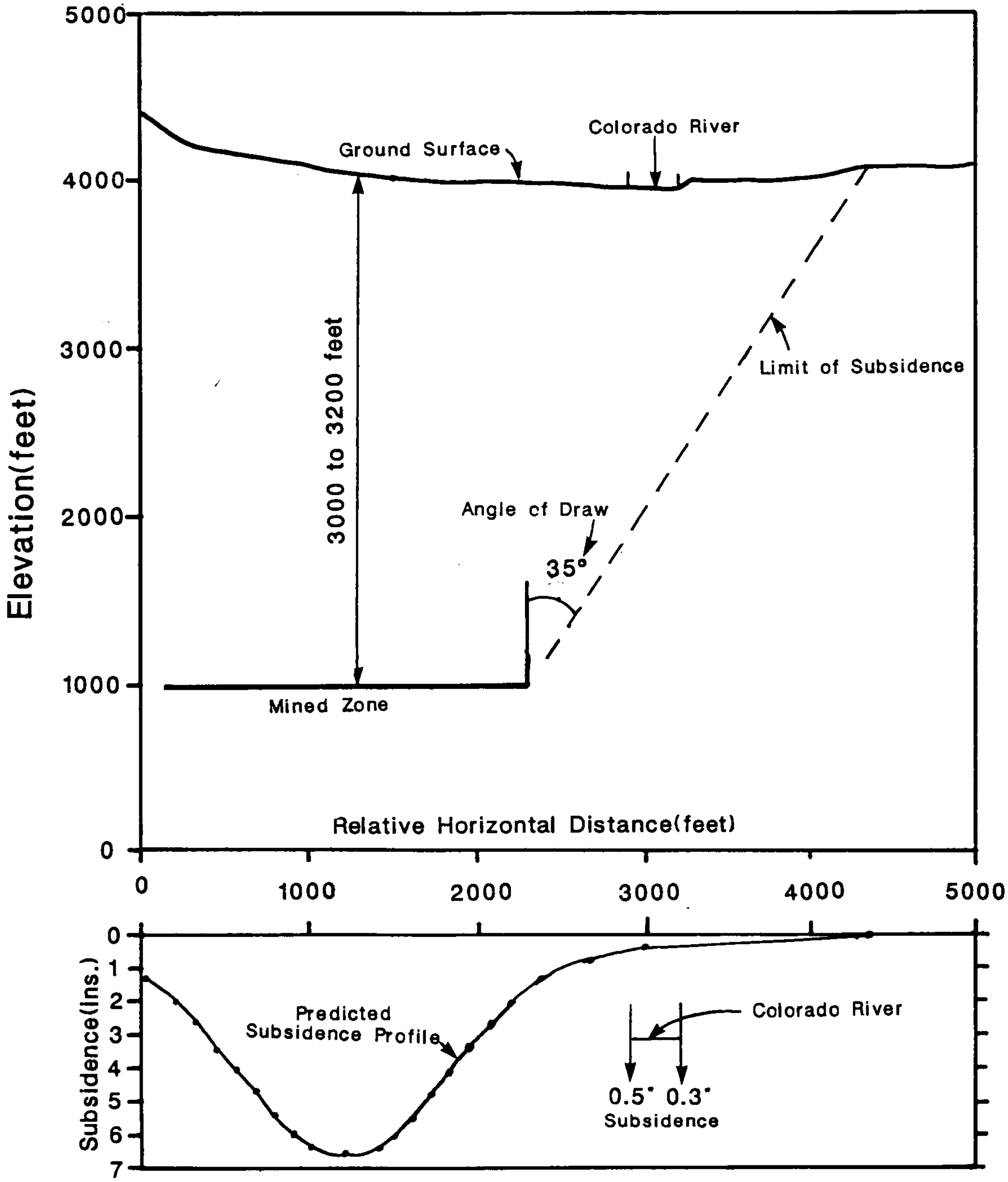


Figure 3
Cross Section C-C'
and
Predicted Subsidence Profile